Optimization of Excavator Boom Cast Part

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Abstract - *With the increasing demand for higher pay loads and accuracy, the design and performance of the backhoe loader is greatly influenced by structural stiffness characteristics. The main objective of structural design is to achieve the minimum mass without compromising the factor of safety. The use of advance technology like finite element method would be of great comfort to perform the structural analysis of backhoe loader components. In this study the focus is on the study of improving the structural strength of fixed link/boom cast part for the given loading conditions*

***Key Words*: Excavator, Backhoe, Boom, Optimization, Cast part**

1. INTRODUCTION

Excavators are heavy duty machines used in earth moving operations like mining, trenching, forestry, demolishing, loading and many other operations. Since they are extensively involved in high loads operations, it is evident that the parts of the excavator have to be strong enough to withstand the operating loads and also the unpredictable loads encountered during its operating stages.

An excavator part consists of the cab, booms and bucket. The cab is fitted to the chassis from where the operator controls the excavator. The cast part is fitted at the front of the cab with the help of fixture assembly. The boom is attached to the front of the excavator through a swing link mechanism.

1.1 Optimizaton

There is always a continuous need for improvements in the existing designs of the products already present in the market in order to cope up with the competition from the other designers and manufacturers. Hence optimization of parts has gained a very popular role in the design field. It is a very challenging task given that the design must meet all the safety standards and must be economical.

2. LITERATURE REVIEW

Jia Yao , et. al[1].The buckling effect on the telescopic boom is studied in this paper. It is important to study the buckling on the telescopic booms because they are used in long tangential reach operations such as in fire fighting trucks. The booms used here are hollow hence the element type used here is SHELL as ANSYS is used in analysis these booms in the paper. The readings from physical model were taken by the dynamic strain reading machine and then the sections were altered to get the reliable design. Jia Yao and Fei Xing[2].This paper studied the behavior of the booms used in cranes under the torsional buckling conditions. It is important for such studies because these booms are subjected to swinging motions during their operation. The failed boom was analyzed where the regions with wrinkles were considered to be the regions with highest stress value. So such regions were optimized to eliminate the stress wrinkles such that the life of boom is increased. Mile Savkovic[3]. This paper studies the stresses across the regions of contact between the two booms in contact during their sliding motion. The contact region stresses are carefully analyzed under the various loading directions imparted during its operation. The paper designs a mathematical model to enable the reliable safe design of the box type booms. The parameters in the mathematical model are the length and thickness of the box shaped booms.

2.1 OUTCOMES FROM LITERATURE SURVEY

Most of the work has been carried out on booms and bucket of excavator. Different analysis such as stress, buckling, torsional, modal analysis has been carried out on booms and bucket applying different boundary conditions. The cast parts such as the swing link and fixed link connected at the excavator front has not been given importance.

2.2 OBJECTIVES

To analyze and compare the stress and displacement plots in excavator boom carrying cast structure for different loading conditions and modifying the boom carrying cast structure geometry and to attain the required factor of safety for the given loading conditions.

2.3 METHODOLOGY

The sliding structure was fabricated in previous excavator assemblies, due to the fabrication, the stresses at the weld regions were crucial and were prone to corrosion which subsequently caused pitting leading to fatigue and crack failures. The sliding structure which supports the whole of the boom structure (swing post, banana boom, dipper and bucket) will bear maximum load compared to any other components of the excavator assembly. The customer requirement is to avoid the weld crack failures, so the design change was required for the sliding structure. The idea was to avoid welding in the sliding member. Hence, the dimensions are taken from the existing reference model and cast mould was designed. Based on the reference dimensions, the CAD part is built using CATIA package.

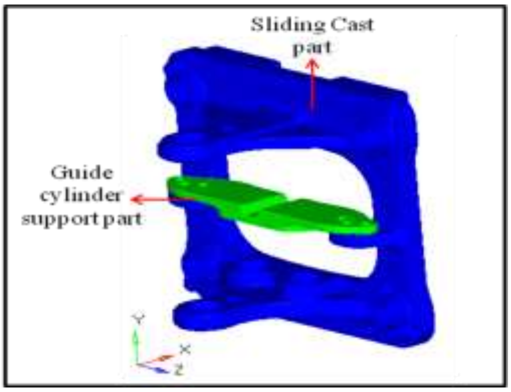

Fig. 1.1 CAD geometry of the excavator boom cast part

The file is exported as a PARASOLID file from the CAD software. The neutral PARASOLID file is imported into the HYPERMESH software for the preprocessing step. The geometric cleanup is done using the cleanup commands of the HYPERMESH. The mesh is carried out using automesh command and the element type used is three noded tria. The average element size is around 5mm. To generate the tetra elements a volume mesh is required. The volume mesh is generated by creating the elements on the outer skin (surface) of the solid body.

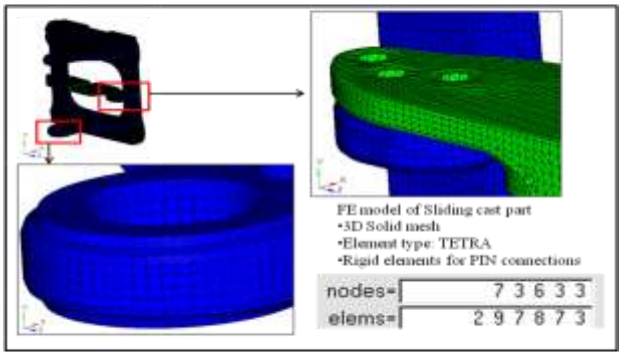

Fig. 1.2.Meshed FE model of the excavator cast part

To ensure the enclosed volume, there should not be any free edges and T-connections in the structure. Once the volume is generated the TETRA that is 4-noded solid mesh of first order is generated. The TET collapse of a TET element is maintained at 0.12. The rigid elements are used to represent the pin joint. The solid section properties and material properties are assigned to the structure. The structure is fixed at four mounting locations at the back of the sliding cast part. The loads are applied at the interconnection joint pins between the swing post and sliding member. The loads are taken from the excavator load capacity chart.

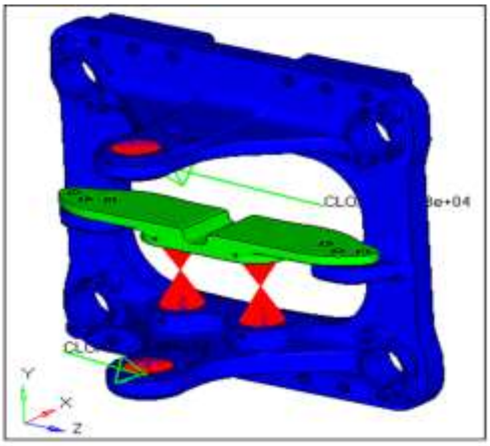

Fig. 1.3 Loads on the boom cast part

The FE model is exported as ABAQUS solver or deck file and is submitted for a run, to solve the analysis. The results are post processed using the .ODB file in the ABAQUS viewer. The stress and displacement plots are discussed in the results and discussion chapter.

3. RESULTS AND DISCUSSIONS

The structure is fixed at four mounting locations at the back of the sliding cast part. The loads are applied at the interconnection joint pins between the swing post and sliding member. The loads are taken from the excavator load capacity chart.

3.1 Load case 1: Load due to digging force acting in X-Y plane .The sliding cast part is analyzed, when the mass of the structure is 222KG.

3.1.1 Von Mises stress

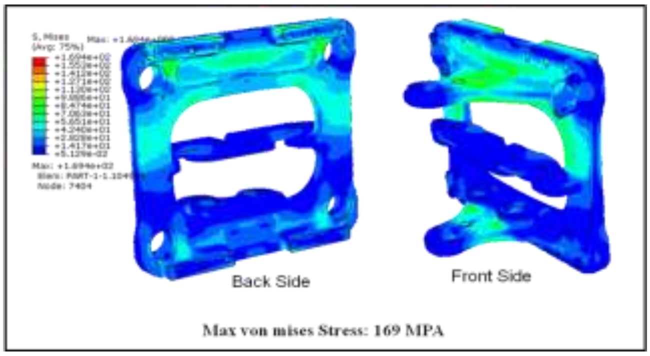

Fig 3.1

The above figure 3.1 shows that the maximum von mises stress for the first load case is 169MPa.

3.1.2 Maximum principal stress

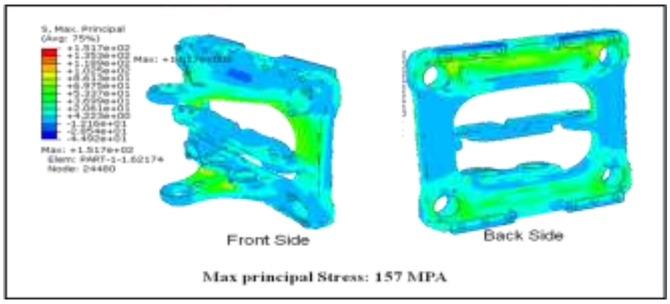

Fig. 3.2

The maximum principal stress of 157Mpa is observed at the front side of the cast part in the figure 3.2 for load case 1 which is loading in X-Y plane experienced during digging operations.

3.1.3 Minimum principal stress

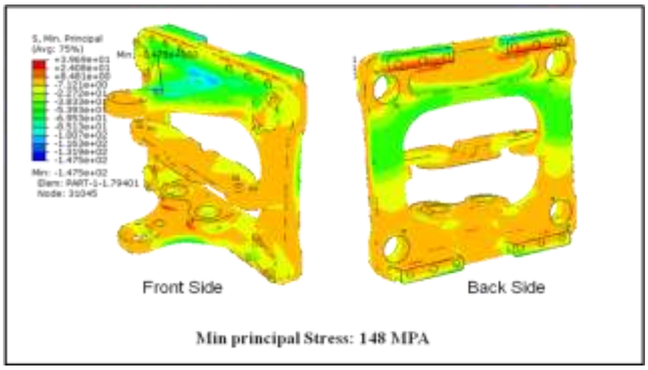

Fig. 3.3

The minimum principal stress in Fig 3.3 is 148MPa for load acting in X-Y plane.

3.1.4 Maximum shear stress

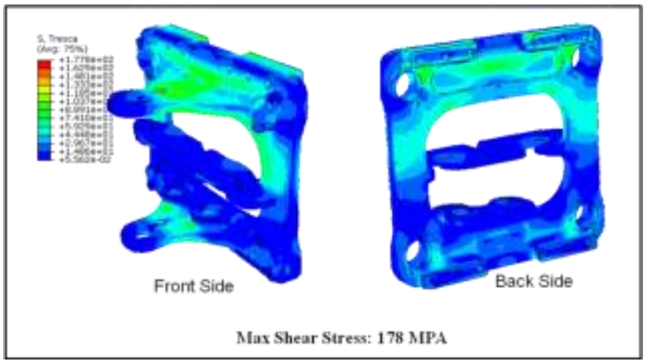

Fig. 3.4

Max shear stress of 178MPa is obtained for first load case in Fig. 3.4

3.2 Load case 2: Load due to bucket dead load in addition to wind load. The sliding cast part is analyzed when the mass of the structure is 222KG.

3.2.1 Von Mises stress

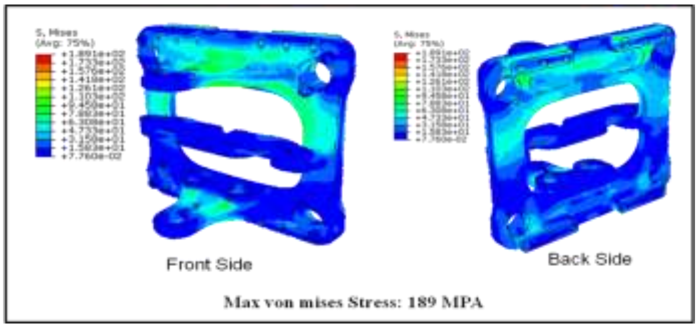

Fig. 3.5

The maximum von mises stress for second loading condition is 189MPa as indicated in Fig. 3.5

3.2.2 Maximum principal stress

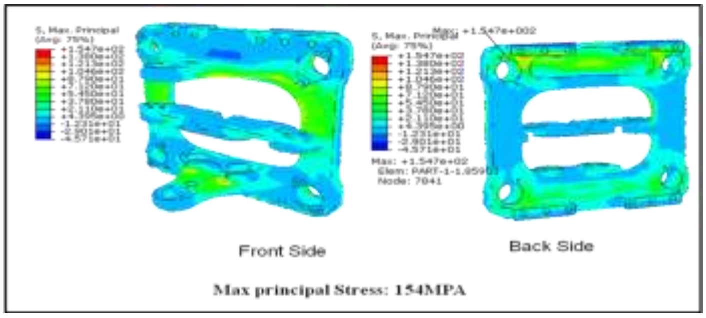

Fig. 3.6

The maximum principal stress is 154Mpa observed at the front side of the cast part in the figure 3.6 for load case 2 which includes the wind loads also.

3.2.3 Minimum principal stress

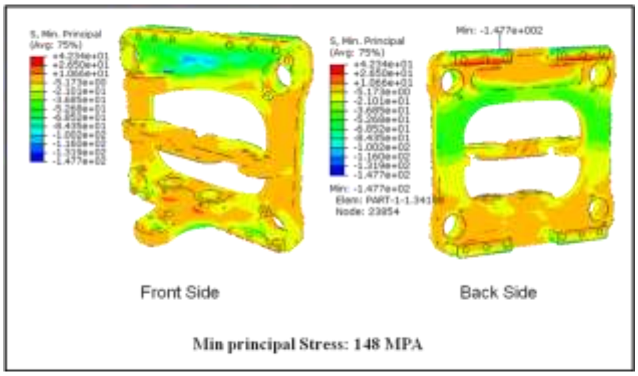

Fig. 3.7 The minimum principal stress is 148MPa from Fig.3.7 for the second loading case.

3.2.4Maximum shear stress

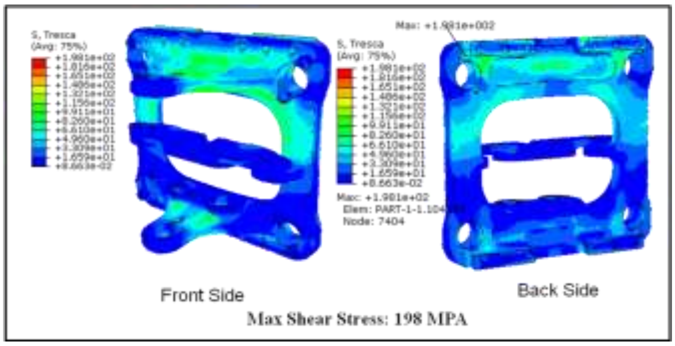

Fig.3.8

Refering to Fig. 3.8 the maximum shear stress is 198MPa for load case 2.

3.3 Load case 1: The mass of structure is 190kg and the load applied is in X-Y direction.

3.3.1 Von Mises stress

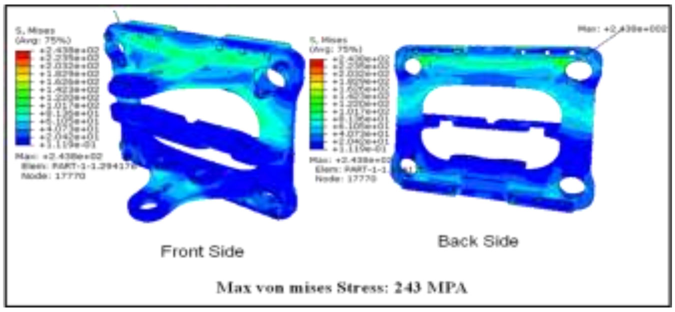

Fig. 3.9

For 190kg of cast structure with case 1 loading condition the maximum von mises stress is 243MPa as represented in Fig. 3.9.

3.3.2 Maximum principal stress

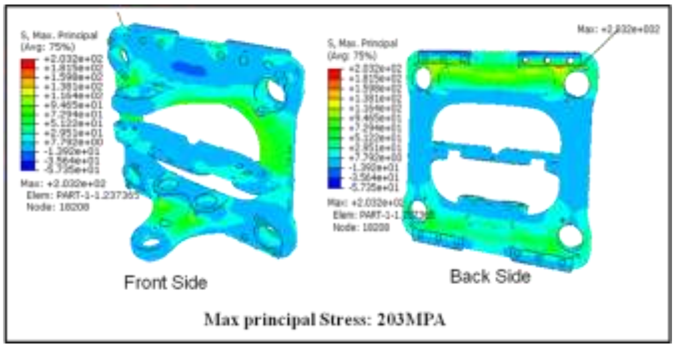

Fig. 3.10

The optimized structure shows a maximum principal stress of 203MPa in Fig. 3.10

3.3.3 Minimum principal stress

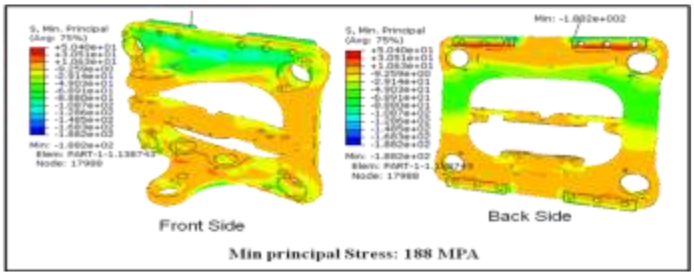

Fig. 3.11

In Fig. 3.11 the minimum principal stress indicated is 188MPa.

3.3.4 Maximum shear stress

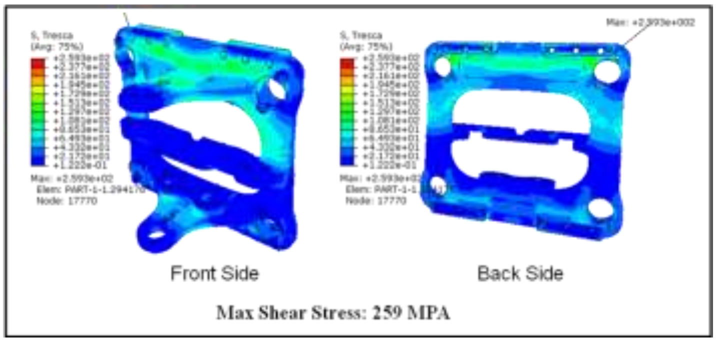

Fig. 3.12

The maximum shear stress of 259MPa is observed for load case 1 in Fig. 3.12 for 190 kg mass structure.

3.4 Load case 2: The structure with 190kg is analyzed taking the wind load into considerations.

3.4.1 Von Mises stress

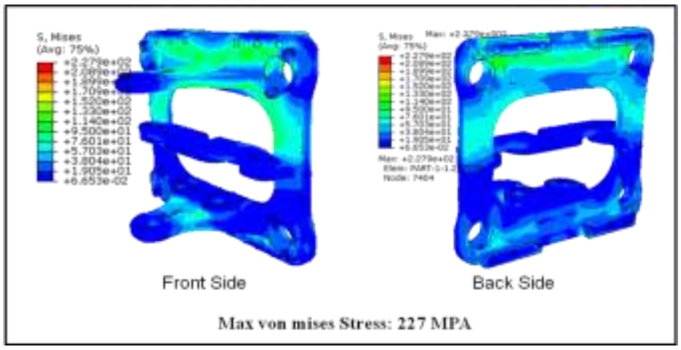

Fig. 3.13

The maximum von mises stress is 227MPa in Fig. 3.13 due to the loads experienced by the boom cast part along with the wind loads in action.

3.4.2 Maximum principal stress

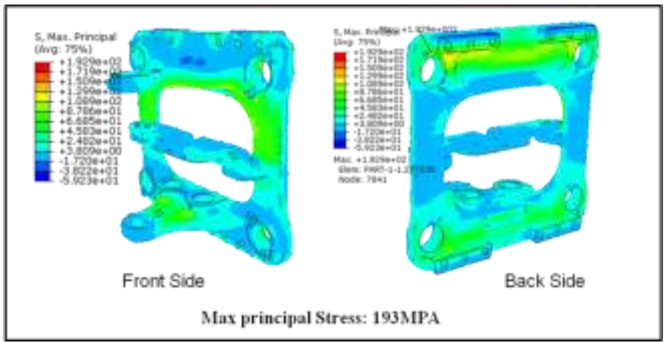

Fig. 3.14

The maximum principal stress is 193MPa in Fig. 3.14 experienced at the contact zone of the structure with the excavator body.

3.4.3 Minimum principal stress

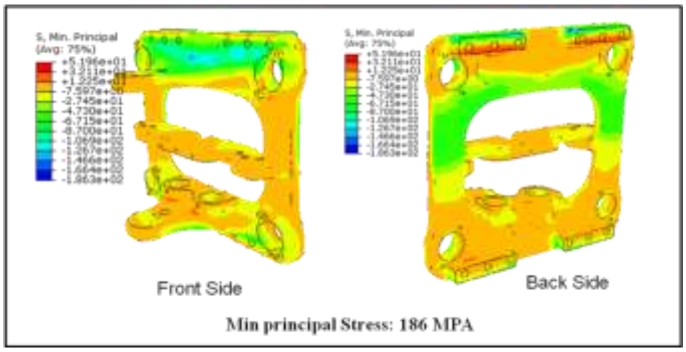

Fig. 3.15

The minimum principal stress for the optimized member in Fig 3.15 is 186MPa.

3.4.4 Maximum shear stress

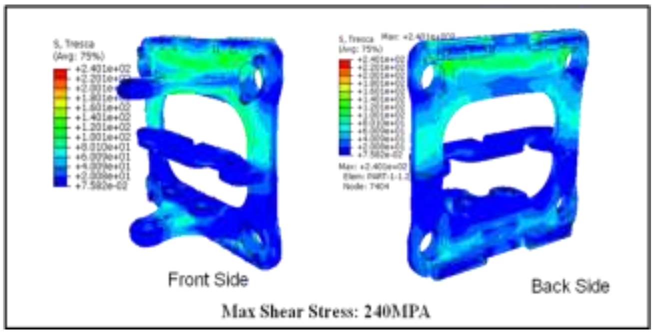

Fig. 3.16

The modified structure in Fig. 3.16 has a maximum shear stress of 240MPa.

Table -3.1: Result Summary

Strength analysis report for 222kg							
Sl.No	Stress (MPa)						
	Von mises	Max Principal	Min Principal	Shear	YS	Max Stress	FOS
LC1	169	157	148	178	550	178	3.09
LC2	189	154	148	198	550	198	2.78
Strength analysis report for 190kg							
LC1	243	203	188	259	550	259	2.12
LC2	227	193	186	240	550	240	2.29

4. CONCLUSIONS AND FUTURE SCOPE

4.1 CONCLUSION

It is observed that the maximum stress in the Sliding cast part weighing 222Kg is 178MPA, when the side wind load is not considered. The maximum stress in the load case 2 (222Kg) where the side wind load is considered is 198MPA which is still lower than the yield strength. The maximum stress observed in the sliding cast part weighing 190 Kg is 259MPA, when the side wind load is not considered. The maximum stress in the load case 2 (190Kg) where the side wind load is considered is 240MPA and it is still lower than the yield strength. The weight of the structure is reduced by 14%, so the material cost involved in manufacturing the structure is also minimized. From the above observation it is evident that the structure is safe for both the load cases. But since there is difference in the weight of the two cast part, the second configuration with weight of 190 Kg should be recommended for manufacturing. The second configuration with weight of 190 Kg is safe with minimum factor of safety 2.12.

4.2 FUTURE SCOPE

In the current study the analysis is carried out with topology approach. Study can be recommended for the shape optimization, where the researcher can concentrate in reducing the localized stresses by modifying the outer surface of the structure.

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[3] Mile Savkovic et al. (2014). “Stress analysis in contact zone between the segments of telescopic booms of hydraulic truck cranes”, Thin-Walled Structures 85,332–340.